Geophysical Research Abstracts,
Vol. 10, EGU2008-A-03919, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-03919
EGU General Assembly 2008

Direct transport process observation in geomaterials: High potential for the GeoPET-method

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We apply the well-established PET method other than in nuclear medicin now as a direct observation technique for process studies in geosciences. As such, positron emission tomography (PET) is about to become an unrivalled method for spatiotemporal direct observations of fluid-bound transport processes in geomaterials.

A commercial PET scanner of the latest generation (ClearPET® by raytest GmbH) with a highly improved resolution of about 1 mm is installed at the IIF and has been successfully tested for the investigation of various transport processes in rock cores. This recently developed GeoPET method allows us to observe solute transport, colloidal transport, reactive transport, fractured fluid flow, diffusive transport and dispersion in heterogeneous structures and experimentally characterize anisotropic geomaterials. In near future, we aim at observing also clogging of pores, matrix diffusion and gaseous transport. In contrast to other tomographic methods the use of radiotracers allows marking of fluid components without affecting their physical and chemical properties, and a most sensitive detection of the tracer. With GeoPET, smallest concentration of the tracer substance (10^9 atoms per voxel) can be determined quantitatively with a maximum frame rate of 1 tomogram per minute. The maximum sample diameter of typical geomaterials is limited by the attenuation length of 511 keV photons to about 10 cm.

The resolution is just the order of the largest pore and fracture sizes in common laboratory samples, and thus the pore space is observed as a continuum. Nevertheless, the effect from smaller pores is still quantitatively related to the integral tracer concentra-

tion in these smaller pores. The spatial variations and statistics of transport properties on the larger scale can be determined quantitatively, because the method implicitly integrates over the representative elementary volume of the pore system.

Although PET is especially suited for long-term flow and diffusion experiments in tight material, because of the high sensitivity and temporal stability of the method, retention by adsorption or volume exclusion of the propagating substance, as well as acceleration caused by preferential flow are directly observable by the spatiotemporal evolution of concentration. Changes of the flow regime over longer periods, which could be caused by alteration processes like clogging of pores, dissolution and precipitation, can be studied. Such long-term experiments with suitable long-living tracers (e.g. ^{58}Co, $T_{1/2}$: 71 days) are currently prepared. Presently, similar experiments in crystalline rocks and clay samples have been conducted over periods of hours (^{18}F, $T_{1/2}$: 1.8 h) up to two weeks (^{124}I, $T_{1/2}$: 4.2 days), demonstrating the feasibility of the method.

These experiments are accompanied by the development of Lattice-Boltzmann modelling methods based on high-resolution CT observations. Thus they will serve for calibrating and enhancing the model code as well as for better understanding and enlightening the processes in the sample, which up to now frequently was observed as black box.